IMPROVING ELECTRICITY MARKET MODEL FOR MALAYSIA ELECTRIC SUPPLY INDUSTRY

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IMPROVING ELECTRICITY MARKET MODEL FOR MALAYSIA ELECTRIC SUPPLY INDUSTRY

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requirements for the award of the degree of
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I declare that this thesis entitled "*Improving Electricity Market Model for Malaysia Electric Supply Industry*" is the results of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Dedicated to

My beloved family

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ABSTRACT

As one of the developing countries, Malaysia has been working on regulatory frameworks and trading arrangement to create more competition in the Malaysia Electricity Supply Industry (MESI) environment. Malaysia has applied single buyer model as its electricity market model since 2001 with Tenaga Nasional Berhad (TNB) responsible in generation, transmission and distribution. However, TNB alone is unable to cater the growth in electricity demand due to rapid development of national economy. Therefore, Malaysia has taken an immense step in MESI by permitting Independent Power Producer (IPPs) to participate in the generation sector. The IPPs and TNB have signed a Power Purchase Agreement (PPA) in which TNB agreed to pay payment for availability to the IPPs regardless of the usage of power generated. The long term PPA caused TNB to suffer massive profit loss due to the capacity payment. The adoption of pool market in MESI will cause high cost IPPs to lose the opportunity to be included in generation dispatch and eventually lose the revenue at low electricity demand. Conversely, the System Marginal Price (SMP) that cleared the market will become too high at peak electricity demand, providing excessive revenue for low cost IPPs. This thesis proposes two electricity markets for MESI. The hybrid market is developed from the original pool market with addition of demand sharing and capacity payment approaches. The second electricity market proposes a single buyer market with fraction capacity payment. The IEEE 14 bus, IEEE 30 bus, Reliability Test System 1996 (Rts96) and Malaysia electricity system were used to illustrate the merit of both proposed markets. Results have shown that hybrid market proposed in this thesis ensures IPPs' participation and provides continuous revenue for all IPPs even at the lowest demand. Meanwhile, the proposed single buyer model has successfully reduced approximately 15.25% of total capacity payment paid by TNB to the IPPs

ABSTRAK

Sebagai negara yang membangun, Malaysia sedang merangka undang-undang dan urus niaga untuk mewujudkan lebih persaingan dalam Industri Bekalan Elektrik Malaysia (MESI). Malaysia telah menggunakan model pembeli tunggal sebagai model pasaran elektrik sejak 2001 di mana Tenaga Nasional Berhad (TNB) bertanggungjawab dalam penjanaan, penghantaran dan pengagihan elektrik. Walau bagaimanapun, TNB sahaja tidak mampu memenuhi kenaikan permintaan elektrik hasil dari pembangunan pesat ekonomi negara. Oleh itu, Malaysia telah mengambil satu langkah yang besar dengan membenarkan Penjana Kuasa Bebas (IPP) mengambil bahagian dalam sektor penjanaan. IPP dan TNB telah menandatangani Perjanjian Pembelian Tenaga (PPA) di mana TNB bersetuju untuk membayar bayaran untuk kesedian kapasiti kepada IPP tanpa mengira penggunaan kuasa yang dihasilkan oleh IPP. Perjanjian jangka panjang ini menyebabkan TNB mengalami kerugian besar akibat pembayaran kapasiti. Adaptasi pasaran kumpulan ke dalam MESI akan menyebabkan IPP dengan kos yang tinggi kehilangan peluang untuk menjana kuasa dan kehilangan pendapatan pada permintaan elektrik rendah. Sebaliknya, Harga Sistem Marginal (SMP) yang terlalu mahal pada permintaan elektrik tertinggi, akan menyebabkan IPP dengan kos rendah menerima pendapatan berlebihan. Tesis ini mencadangkan dua pasaran elektrik untuk MESI. Pasaran hibrid dibangunkan dari pasaran kumpulan dan ditambah pendekatan perkongsian permintaan dan pembayaran kapasiti. Pasaran elektrik kedua dicadangkan adalah pasaran pembeli tunggal dengan sebahagian bayaran kapasiti. IEEE 14 bas, IEEE 30 bas, Kebolehpercayaan Sistem Ujian 1996 (Rts96) dan sistem elektrik Malaysia telah diguna untuk menunjukkan kelebihan kedua-dua pasaran dicadangkan. Hasil kajian menunjukkan pasaran hibrid yang dicadangkan dalam tesis ini dapat menjamin penyertaan dan pendapatan yang berterusan untuk IPP walaupun pada permintaan terendah. Sementara itu, model pembeli tunggal yang dicadangkan telah berjaya mengurangkan kira-kira 15.25% daripada jumlah pembayaran kapasiti yang perlu dibayar oleh TNB kepada IPP.

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LIST OF SYMBOLS

$	-	Dollar
$/h	-	Dollar per hour
$/MW/month	-	Dollar per Megawatt per month
$/MWh	-	Dollar per Megawatt hour
MW	-	Megawatt
MWh	-	Megawatt hour
RM	-	Ringgit Malaysia
RM/h	-	Ringgit Malaysia per hour
RM/MW/month	-	Ringgit Malaysia per Megawatt per month
RM/MWh	-	Ringgit Malaysia per Megawatt hour

LIST OF ABBREVIATIONS

CEB	-	Central Electricity Board
DISTCO	-	Distribution company
EC	-	Energy Commission
EGAT	-	Electricity Generating Authority of Thailand
EMA	-	Energy Market Authority
EMC	-	Energy Market Company
ESB	-	Enhanced Single Buyer
ESI	-	Electricity Supply Industry
FERC	-	Federal Energy Regulatory Commission
GENCO	-	Generation company
IEEE	-	Institute of Electrical and Electronics Engineers
IGSO	-	Independent Grid System Operator
IMO	-	Independent Market Operator
IPP	-	Independent Power Producer
LOLP	-	Loss of load probability
M-co	-	Marketplace Company
MEA	-	Metropolitan Electricity Authority
MESI	-	Malaysia Electricity Supply Industry
NAPOCOR	-	National Power Corporation
NEB	-	National Electricity Board
NEMS	-	National Electricity Market of Singapore
NEPO	-	National Energy Policy Office
NESA	-	New Electricity Supply Arrangement
NUG	-	Non-utility generator

PEA	-	Provincial Electricity Authority
PLN	-	Perusahaan Listik Negara
PPA	-	Power Purchase Agreement
PPP	-	Pool Purchase Price
PSA	-	Power Sales Agreement
PSP	-	Pool Selling Price
PUB	-	Public Utilities Board
PX	-	Power exchange
RTS	-	Reliability Test System
SB	-	Single Buyer
SEP	-	Singapore Electricity Pool
SESB	-	Sabah Electricity Sdn. Bhd.
SESCO	-	Sarawak Electricity Supply Corporation
SMP	-	Single Marginal Price
SO	-	System Operator
SP	-	Singapore Power
ST	-	Suruhanjaya Tenaga
SRC	-	State Regulatory Commission
TNB	-	Tenaga Nasional Berhad
TNBG	-	Tenaga Nasional Berhad Generation
TRANSCO	-	Transmission company
TSA	-	Transmission Service Agreement
VOLL	-	Value of loss load

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

For many decades, the vertically integrated utility has been dominating the electricity industry throughout the world. The vertically integrated utility is needed so that the process of buying and selling of electricity could be done smoothly. The utility in vertically integrated monopoly structure has full control on generation, transmission, and distribution sectors as illustrated in Figure 1.1. The de-regulation of electricity market is required to replace the vertically integrated utility which monopoly in selling and distribution of electricity into a more competitive market. The de-integration of electricity industry is possible after the existence of the grid where generation is split off to form a separate competitive market [1]. By 1990, a huge transformation in the electricity industry took place in many countries after being encouraged by the general trend toward deregulation.[1, 2]. In the early days, the purpose of deregulation was to decrease the market price for consumer [3]. Currently, the central focus for restructuring is to introduce competition into generation and supply with the aims for better economic performance, improved risk allocation, and lower prices for consumers [4].

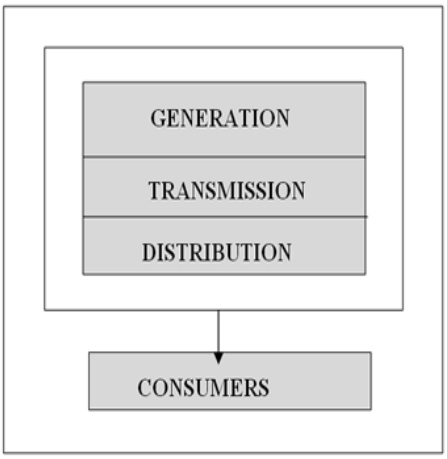

Figure 1.1 The vertically integrated structure

Under restructuring model, the utilities are required to unbundle the retail services so that three separated groups can be formed to represent the generation companies (GENCOs), transmission companies (TRANSCOs), and distribution companies (DISTCOs). The structure of the electricity industry after restructuring is shown in Figure 1.2. The deregulation of the electricity industries varies for each country depending on its politics, economics, and regulatory needs [5]. These characteristics play huge roles to determine the best fitted electricity market model to be applied for each country.

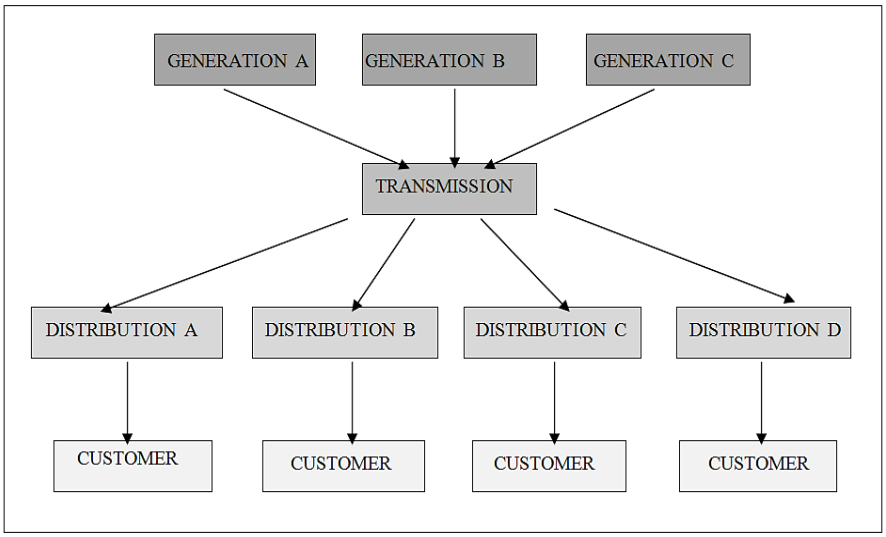

Figure 1.2 The electricity industry after restructuring

There are several types of the electricity market model available in deregulated structure such as single buyer market, pool market, bilateral contract, and multilateral contract. Each electricity market has its own distinct characteristic. The further details on the characteristic of the four electricity markets are summarized in Table 1.1.

Table 1.1: The types of electricity market model

Electricity Market Model	**Descriptions**
Single buyer market	(a) Preferred electricity market model as the first step towards restructuring the ESI [6] (b) Single buyer market buy power from its own generators or the IPPs (c) IPPs usually signed PPA with the purchasing agency (d) PPA includes two payments: ▪ energy payment to cater variation of demand ▪ capacity payment to cover the capital costs of the generators [7]
Pool market	(a) Two main participants in pool model are producer or suppliers and customers or consumers (b) The pool operator (IMO) will attain the economic dispatch [7, 8] (c) Consists of two stages: ▪ unconstrained dispatch ▪ security constrained dispatched (d) The last generator being dispatched will determine the system marginal price (SMP)
Bilateral contract	(a) The two market participants are electricity buyer and seller (b) Allows electric power exchange such as MW amount, time of delivery, duration, and price [9] (c) A buyer or seller has opportunity to choose the

	suppliers they want to negotiate with[10] (d) No capacity payment involve in the market
Multilateral contract	(a) Combines the pool and bilateral model (b) Utilizing power exchange is not required (c) Allows customers to sign bilateral contract and choose supplier from the pool (d) Customers who choose not to sign bilateral contract will be served by the pool (e) It is a highly costs electricity market model

In line with the development of its various economic sectors, Malaysia has taken the first step towards a competitive electricity market by introducing the independent power producers (IPPs) in 1992. The IPPs owns facilities to produce electric power and responsible to help the national power company, Tenaga Nasional Berhad (TNB) to cater the growth in electricity demand in Malaysia. Malaysia applied single buyer market as the new structure of Malaysia electric supply industry (MESI) since 1992 [6, 11]. A power purchase agreement (PPA) is signed between TNB and the IPPs which act as the legal contract between these two parties [4]. This long term contract which last for 21 years requires TNB to pay IPP using two types of payment; capacity charges which a fixed payment must be paid to the IPPs regardless the power usage and energy charges which is paid based on the amount of power usage. After several years, the TNB suffers massive profit loss but the IPPs enjoy secured incomes through the capacity charge stated in PPA [11]. No action has been taken as the IPPs strongly refused to renegotiate the agreement ever since the request started in 2006 until today where the contract is about to end [6].

1.2 Objectives of the Study

This study focuses on the following objectives:

(a) To study current electricity market model applied by MESI (Malaysia Electric Supply Industry) and other types of electricity trading arrangement applied in deregulated structure.

(b) To propose a convenient approach to improve the existing market model in MESI.

(c) To study and develop hybrid market model for MESI.

1.3 Scope of Study

A thorough study is done on several existing worldwide market models such as single buyer market, pool market, bilateral market and hybrid market. The experience of other countries with different electricity market model shows the pros and cons of each market model. This study is focusing on the current electricity market in Malaysia, single buyer market and the future recommended electricity market for MESI, the pool market. Examples of the application of these electricity markets will be analysed to show the comparison of both markets in certain aspects such as producers' power contribution and producers' revenue.

This study aims to develop a market model that can satisfy both producers and customers in Malaysia. These can be achieved by improving the current electricity market by adjusting the payment mechanism in the single buyer market from full payment into fraction payment to make it fair for all participants. Otherwise, additional approach can be added to modify the pool market for future electricity market. The weakness of pool market to guarantee continuous revenue for producers can be solved by applying demand sharing mechanism, which distributes the electricity demand equally among producers. Therefore, in this study, the best

approach to improve the shortcomings from both electricity markets is determined in order to develop a new market model compatible with MESI environment.

1.4 Problem Statement

TNB as the national power company is responsible in generation, transmission, and distribution of electricity in MESI. However, after a major nationwide blackout for two days in September 1992, Malaysia government took a drastic step which dismantled the TNB monopoly in electricity generation and initiated the IPPs program [6, 12, 13]. As the TNB was incapable to cater the growth in electricity demand, the IPPs participation in generating sector seem to be the only solution to avoid the short of electricity.

On 31 March 1993, PPA is signed between the TNB and the first five IPPs [12]. This 21 years long term contract required TNB to pay two payments to the IPPs. The first payment is energy payment, paid for electricity consumed by the TNB. The second payment is capacity payment, paid for the IPPs' available capacity. This capacity payment is paid to IPPs even though the power generated from these IPPs is not being used. As the only power off taker, TNB suffered massive profit loss due to high expenses on this capacity payment [6]. In contrast, the IPPs enjoy irrelevant incomes and have no fear, even if they are not generating as the profits were almost guaranteed through capacity payment.

Regarding this issue, the fact that the PPA is almost comes to end must be considered. All IPPs must have recovered their investment within this agreement period. Therefore, there is no need to pay the power producers with full capacity payment which used to cover the capital and other fixed costs. An adjustment has to be made to the capacity payment mechanism to reduce the TNB profit loss. Otherwise, single buyer market must be replaced with another market model, which can fairly divides the profits among the TNB and the IPPs.

Pool market is a simple market model with only one payment paid to power producers. Even so, implementation of this market in Malaysia is not that simple. There are several factors must be taken into consideration such as power producers' welfare and risks for customers. The main concern in the pool market is that the hierarchy of power producers to meet the demand is depending too much on the energy bid price. Some of the power producers in Malaysia are ageing and less efficient. Thus, the production costs might increases, and these producers will have fewer opportunities to sell their output. The priority to supply electricity in the pool market is given to the producers with a least-expensive energy bid price. During low electricity demand, expensive power producers will lose in biding and suffer zero revenue.

In addition, it appears that the pool price is highly depended on the power producers' bidding. Therefore, without conscientious observation on the producer's bidding price, the market price can be extremely high during peak electricity demand. Power producers might receive excessive revenue due to reckless bid while the customers have to bear the consequences.

The proposed market models are intended to improve the existing single buyer market and pool market. These markets reduced the burden endured by the national power company and at the same time taking care of the power producers' welfare. Moreover, customers will enjoy better electric facilities at reasonable price. The new approach proposed in each market model is expected to be able to solve the market's problem in order to satisfy all power producers, national power company, as well as electric customers in the MESI.

1.5 Significant of Research

This research has made several contributions as follow:

a) Proposes new electricity market model that improve the weaknesses of the current single buyer market and the future recommended market, pool market.
b) Mathematical formulations of the new hybrid market and single buyer market with fraction capacity payment.

1.6 Thesis Organization

This thesis consists of six chapters and is organized as follows:

Chapter 1 describes the overview of the study which includes the objectives, scope of study, problem statement and the methodology used to achieve the aims of this study. Next, Chapter 2 highlights the restructuring of electricity supply industry, including the experience of several countries with ESI restructuring. The details on IPPs and PPA are discussed further in this chapter. This chapter also elaborated various the electricity markets available in deregulated structure.

The restructuring of the Malaysia Electricity Supply Industry (MESI) is discussed in Chapter 3. This chapter gives a depth explanation on the current electricity market applied by MESI, which is a single buyer market. Subsequently, this chapter also discussed in the pool market model as the highly recommended market model to replace the single buyer market in Malaysia. Besides, issues raised regarding both market models are stressed in this chapter. Simple analysis is executed for both markets to show the pros and cons of each market model.

Chapter 4 emphasized on the new approaches proposed for single buyer market and pool market. Prior to the shortcomings from the current electricity

market and future market, two electricity markets are proposed in this chapter. The hybrid market is proposed to overcome the flaws in pool market using demand sharing and capacity. On the other hand, the second market is proposed to improved single buyer market by making an adjustment of the capacity payment mechanism. The structures of both methods proposed are discussed briefly in this chapter.

Several case studies consist of three test system will be elaborated in Chapter 5. The purpose of this case study is to compare the proposed electricity markets with the original markets in terms of power contribution and welfare of the power producers, which in this study referred to the IPPs. Simulation results and discussion are also included. Finally, Chapter 6 concludes the study with some suggestions for future works in order to improve the current work.

REFERENCES

[1] S. Stoft, "Power System Economics: Designing Markets for Electricity," *IEEE Press*, 2002.

[2] G. S. Rothwell and T. Gómez, "Electricity economics: regulation and deregulation," *John Wiley*, vol. 12, 2003.

[3] R. Li, L. Chen, and R. Yokoyama, "A methodology for evaluating the wholesale/retail prices in deregulation market," in *Power Tech Conference Proceedings, 2003 IEEE Bologna*, 2003, p. 7 pp. Vol.1.

[4] C. Celik, "Electric Power Market Models in Developing Countries," *Istanbul Bilgi University*.

[5] M. F. de Oliveira, R. C. G. Teive, and G. A. B. Arfux, "The deregulation process of the electrical sector into practice - A comparison between developed and developing countries," *2004 IEEE/PES Transmission & Distribution Conference & Exposition: Latin America*, pp. 815-819, 2004.

[6] M. A. C. Aziz, "Malaysia Power Purchased Agreement and Competitive Power Market Model," *Universiti Teknologi Malaysia*.

[7] M. Y. Hassan, M. P. Abdullah, A. S. Arifin, F. Hussin, and M. S. Majid, "Electricity Market Models in Restructured Electricity Supply Industry," *2008 Ieee 2nd International Power and Energy Conference: Pecon, Vols 1-3*, pp. 1038-1042, 2008.

[8] S. Chaitusaney and B. Eua-Arporn, "Actual social welfare maximization in pool market," in *Power Engineering Society Summer Meeting, 2002 IEEE*, 2002, pp. 1553-1558 vol.3.

[9] S. El Khatib and F. D. Galiana, "Negotiating bilateral contracts in electricity markets," *Ieee Transactions on Power Systems*, vol. 22, pp. 553-562, May 2007.

[10] A. Shabani, H. Hosseini, H. K. Karegar, and S. Jalilzadeh, "Optimal Generation Expansion Planning in IPP Presence with HCGA," *2008 Ieee 2nd International Power and Energy Conference: Pecon, Vols 1-3*, pp. 143-147, 2008.

[11] A. S. Arifin, "A Pool Based Electricity Market Design for Malaysia Electricity Supply Industry," *Universiti Teknologi Malaysia*, 2008.

[12] N. Z. Mohd Zamin, N. Z. Zainol Abidin, and J. B. Ibrahim, "Single buyer - A step forward in Malaysian Electricity Supply Industry reform," in *TENCON Spring Conference, 2013 IEEE*, 2013, pp. 391-397.

[13] D. Nikomborirak and W. Manachotphong, "Electricity Reform in Practice: The Case of Thailand, Malaysia, Indonesia, and the Philippines," *Intergovernmental Group of Experts on Competition Law and Policy*, 17-19 July 2007.

[14] D. S. Kirschen and G. Strbac, "Fundamentals of Power System Economics," *John Wiley & Sons*, 2004.

[15] M. Shahidehpour, H. Yamin, and Z. Li, "Market Operations in Electric Power Systems: Forecasting, Scheduling, and Risk Management," *Wiley-IEEE Press*, March 2002.

[16] A. Jayantilal, K. W. Cheung, P. Shamsollahi, and F. S. Bresler, III, "Market based regulation for the PJM electricity market," in *Power Industry Computer Applications, 2001. PICA 2001. Innovative Computing for Power - Electric Energy Meets the Market. 22nd IEEE Power Engineering Society International Conference on*, 2001, pp. 155-160.

[17] N. Leeprechanon, A. K. David, S. S. Moorthy, and L. Fubin, "Transition to an electricity market: a model for developing countries," *Power Systems, IEEE Transactions on*, vol. 17, pp. 885-894, 2002.

[18] T. Nakashima and T. Niimura, "Multiple-impact assessment of independent power producers in a de-regulated environment," in *Electrical and Computer Engineering, 1997. Engineering Innovation: Voyage of Discovery. IEEE 1997 Canadian Conference on*, 1997, pp. 273-276 vol.1.

[19] H. Nagayama, "Electric power sector reform liberalization models and electric power prices in developing countries An empirical analysis using international panel data," *Energy Economics*, vol. 31, pp. 463-472, May 2009.

[20] T. Jamasb, "Between the state and market: Electricity sector reform in developing countries," *Utilities Policy*, vol. 14, pp. 14-30, 3// 2006.

[21] D. Newbery, "Issues and Options for Restructuring Electricity Supply Industries," *Department of Applied Economics University of Cambridge*, 2002.

[22] P. L. Joskow, "Electricity Sector Restructuring and Competition : Lessons Learned," *MIT Center for Energy and Environmental Policy Research, Massachusetts Institute of Technology,* August 2003.

[23] C. S. Greacen and C. Greacen, "Thailand's Electricity Reforms: Privatization of Benifits and Socialization of Costs and Risks," *Pacific Affairs,* vol. 77, 2004.

[24] P. Punjad, T. Tantimaporn, and J. Chaiyabin, "Experience of introducing new regulatory policy on electricity supply industry of Thailand," in *Electricity Distribution - Part 1, 2009. CIRED 2009. 20th International Conference and Exhibition on*, 2009, pp. 1-4.

[25] C. Chompoo-inwai, C. Yingvivatanapong, P. Fuangfoo, and L. Wei-Jen, "Transmission congestion management during transition of electricity deregulation in Thailand," in *Industry Applications Conference, 2005. Fourtieth IAS Annual Meeting. Conference Record of the 2005*, 2005, pp. 2665-2671 Vol. 4.

[26] Y. Wu, "Electricity market integration: Global trends and implications for the EAS region," *Energy Strategy Reviews,* vol. 2, pp. 138-145, 9// 2013.

[27] C. Youngho and T. Tuan Hin, "Price responsiveness in the new electricity market: a Singapore experience," in *Electric Utility Deregulation, Restructuring and Power Technologies, 2004. (DRPT 2004). Proceedings of the 2004 IEEE International Conference on*, 2004, pp. 44-48 Vol.1.

[28] Y. H. Chang, "Deregulation in the national electricity market of Singapore: competition and efficiency," in *Electric Utility Deregulation, Restructuring and Power Technologies, 2004. (DRPT 2004). Proceedings of the 2004 IEEE International Conference on*, 2004, pp. 16-19 Vol.1.

[29] Y. Chang, "The New Electricity Market of Singapore: Regulatory framework, market power and competition," *Energy Policy,* vol. 35, pp. 403-412, 1// 2007.

[30] L. Feiyu and H. Gan, "National Electricity Market of Singapore," in *Power Engineering Conference, 2005. IPEC 2005. The 7th International*, 2005, pp. 1007-1012 Vol. 2.

[31] "Energy Market Authority News Release," 10 October 2003.

[32] D. Sharma, "Electricity Reforms in the ASEAN: A Panoramic Discourse," *Economic and Political Weekly,* vol. 40, p. 9, 2005.

[33] P. Pintz and A. Korn, "Developement of a Competitive Electricity Market in Indonesia," *Energy Studies Review,* vol. 13, 5 January 2005.

[34] I. M. R. Sakya, U. R. Simanjutak, P. H. Schavemaker, and L. van der Sluts, "Experience with internal competition using the single buyer model in Jawa Bali - Indonesia," in *Power Systems Conference, 2006. MEPCON 2006. Eleventh International Middle East*, 2006, pp. 601-605.

[35] H. Nagayama, "Electric power sector reform liberalization models and electric power prices in developing countries: An empirical analysis using international panel data," *Energy Economics,* vol. 31, pp. 463-472, 5// 2009.

[36] C. S. Ozveren, D. King, and K. Mursitojati, "Power sector reform in Indonesia What should be policy for the state owned power company (PLN)," in *Universities Power Engineering Conference, 2008. UPEC 2008. 43rd International*, 2008, pp. 1-5.

[37] N. Othman, M. Y. Hassan, F. Hussin, and M. P. Abdullah, "Generation Dispatch with minimum load sharing in pool trading model," *in Asia Pasific Coonference on Engineering Technopreneurship (ACET)* pp. 86-91, 23-24 Oct. 2012.

[38] EPSA. Electricity Primer - The Basics of Power and Competitive Markets. *What Is a Wholesale Electricity Market?* Available: http://www.epsa.org/industry/primer/?fa=wholesaleMarket

[39] EPSA. Electricity Primer - The Basics of Power and Competitive Markets. *How Is Electricity Sold At Retail?* Available: http://www.epsa.org/industry/primer/?fa=sold

[40] P. Stephenson and M. Paun, "Electricity market trading," *Power Engineering Journal,* vol. 15, pp. 277-288, 2001.

[41] A. Kumar and G. Wenzhong, "Social welfare based nodal pricing with FACTS cost models in hybrid electricity markets," in *Innovative Smart Grid Technologies (ISGT), 2012 IEEE PES*, 2012, pp. 1-8.

[42] "CER Factsheet on the Single Electricity Market," *Commission for Energy Regulation,* April 2001.

[43] N. Othman, M. Y. Hassan, and F. Hussin, "Generation revenue assessment in pool-based electricity markets," in *2012 IEEE International Conference on Power and Energy (PECon)*, 2012, pp. 206-211.

[44] A. Nitanan and K. Audomvongseree, "Electricity insurance pricing for the bilateral contract market," in *Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2011 8th International Conference on*, 2011, pp. 812-815.

[45] e. Contributor. *The Definition of a Power Purchase Agreement*.

[46] R. Proctor, B. Fox, and D. Flynn, "Reserve trading within power purchase agreements," in *Electric Utility Deregulation and Restructuring and Power Technologies, 2000. Proceedings. DRPT 2000. International Conference on*, 2000, pp. 137-141.

[47] L. A. Barroso, A. Street, S. Granville, M. Pereira, J. Rosenblatt, J. Cahuano, *et al.*, "Market models & monitoring: assessing new techniques for long-term PPA auctions to support long-run policy decisions in Brazil," in *Power Engineering Society General Meeting, 2005. IEEE*, 2005, pp. 2031-2033 Vol. 2.

[48] V. Marques, C. Vaz, and P. Verdelho, "Incentive for the profit maximization of binding generation in a market environment," in *Electricity Market, 2008. EEM 2008. 5th International Conference on European*, 2008, pp. 1-5.

[49] R. Billinton and S. Adzanu, "Reliability cost/worth analysis of nonutility generation," in *Electrical and Computer Engineering, 1996. Canadian Conference on*, 1996, pp. 420-423 vol.1.

[50] E. L. Fytche and B. Gallagher, "Risk for an independent power producer (IPR)," in *Renewable Energy - Clean Power 2001, 1993., International Conference on*, 1993, pp. 95-99.

[51] D. G. Victor, T. C. Heller, J. C. House, and P. Y. Woo, "Experience with Independent Power Projects (IPPs) in Developing Countries: Introduction and Case Study Methods," *Program on Energy and Sustainable Development Working Paper,* April 2004.

[52] "Philippines Power Sector Study: Structural Framework for the Power Sector," *World Bank,* 30 November 1994.

[53] E. J. Woodhouse, "The IPP Experience in the Philippines," *Stanford University,* September 2005.

[54] J. Rector, "The IPP Investment Experience in Malaysia," *Stanford University,* 17 August 2005.

[55] D. G. Victor, T. C. Heller, J. C. House, and P. Y. Woo, "Experience with Independent Power Projects (IPPs) in Developing Countries: Introduction and Case Study Methods," *Stanford University,* April 2004.

[56] T. B. Smith, "Privatising Electric Power in Malaysia and Thailand: Politics and Infrastructre Development Policy," *Department of Social and Behavioral Sciences, Zayed University,* 2003.

[57] A. d. Oliveira, E. J. Woodhouse, Luciano, Losekann, and F. V. S. Araujo, "The IPP Experience in the Brazilian Electricity Market," *Stanford University,* October 2005.

[58] F. Cavaliere de Souza and L. F. Loureiro Legey, "Brazilian electricity market structure and risk management tools," in *Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE,* 2008, pp. 1-8.

[59] A. A. Abidin, "Electric Supply Industry of Peninsular Malaysia [Asian and Australian Power Policy]," *Power Engineering Review, IEEE,* vol. 16, p. 15, 1996.

[60] A. Akhtar, A. Asuhaimi, H. Shaibon, and K. L. Lo, "Development of privatized power industry in Malaysia," in *Opportunities and Advances in International Electric Power Generation, International Conference on (Conf. Publ. No. 419)*, 1996, pp. 29-33.

[61] A. Khamis, A. Alamshah, A. Ahmad, A. Ab Rahman, and M. H. Hairi, "Energy & electricity consumption analysis of Malaysian power demand," in *Power Engineering and Optimization Conference (PEOCO), 2010 4th International*, 2010, pp. 463-467.

[62] M. Shekarchian, M. Moghavvemi, T. M. I. Mahlia, and A. Mazandarani, "A review on the pattern of electricity generation and emission in Malaysia from 1976 to 2008," *Renewable and Sustainable Energy Reviews,* vol. 15, pp. 2629-2642, 8// 2011.

[63] N. Othman, M. Y. Hassan, F. Hussin, and M. P. Abdullah, "Generator Revenue Adequacy in the Competitive Electricity Markets: The case of Malaysia," *International Journal of Integrated Engineering,* vol. 5, pp. 26-35, 2013.

[64] K. F. See and T. Coelli, "The Effects of Competition Policy on TFP Growth: Some Evidence from the Malaysian Electricity Supply Industry," *School of Economics University of Queensland St. Lucia,* August 2009 2009.

[65] A. Sultana, "Pool versus Bilateral Markets: A Global Overview," *University of Waterloo, Canada,* 2004.

[66] S. Chaitusaney and N. Hoonchareon, "Generation dispatch with pool and bilateral coordination," in *Power System Technology, 2002. Proceedings. PowerCon 2002. International Conference on*, 2002, pp. 1355-1359 vol.3.

[67] K. L. Low, "Power System Economics," *Lecture Notes, Strathclyde University,* 2002.

[68] A.-A. H. M. Soliman Abdel-Hady Soliman, *Modern Optimization Techniques with Applications in Electric Power Systems*: Springer, 2011.

[69] Z. H. O. Heba A. Hassan, Abd El-Aziz Lasheen, "Sizing of STATCOM to Enhance Voltage Stability of Power Systems for Normal and Contingency Cases," *Smart Grid and Renewable Energy,* vol. 5, p. 11, 2014.

[70] F. Xiao, I. S. U. Electrical, and C. Engineering, *Risk Based Multi-objective Security Control and Congestion Management*: Iowa State University, 2007.